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(54) **EXTERNALLY MOVEABLE INTRACAVITY PROBE FOR MRI IMAGING AND SPECTROSCOPY**

VON AUSSEN BEWEGBARE KÖRPERSONDE ZUR MRI-BILDERZEUGUNG UND ZUR
SPEKTROSKOPIE

SONDE COLIQUE POUR IMAGERIE PAR RESONANCE MAGNETIQUE ET SPECTROSCOPIE

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Description

Background of the Invention

This invention relates to a receiving device in the form of an intracavity probe for use in magnetic resonance imaging (MRI) and spectroscopy systems to enhance the imaging performance and spectroscopy sensitivity of such instruments when evaluating anatomical regions small in size relative to the body, and deep within the body, but proximate a location where an insertable pickup probe can be used. Specifically, the present invention relates to an intracavity pickup probe especially useful to image the colon region by rectal introduction, but which may also be useful for inspecting other regions of the body by suitable intracavity insertion.

In the field of MRI systems, also commonly known as NMR imaging systems, external pickup probes are typically used for receiving radio frequency signals from the region of interest. For optimum performance when imaging certain select parts of the body, the pickup probe should be insertable for intracavity use and include a radio frequency receiving coil, to be positioned as close to the region of interest as possible. In addition, the insertable pickup probe should also have a sensitive volume equaling the desired field of view of the region of interest. This allows optimization of the "filling factor" and "coupling coefficient" for the specific MRI system, thereby improving signal to noise ratio in MR imaging.

Furthermore, for optimum sensitivity, the receiving coil should have a loaded coil quality factor (Q) which is as great as possible and should be adjusted to resonate at the exact Larmour frequency of the scanner of the MRI system. It also sometimes is desired that the insertable, intracavity pickup probe be disposable, and hence the cost of the probe should be minimized as much as possible. At the same time, it is important that in reducing the cost of the probe, the ability to impedance match and tune the receiving coil to the scanner of the MRI system not be compromised. Therefore, there is a need to provide a disposable pickup probe at minimal cost for use in a MRI system which is capable of automatic or manual tuning and impedance matching of the receiving coil to the scanner of the MRI system.

US patent No. 4,960,106 discloses an NMR metering endoscope apparatus which comprises an elongate insertable intracavity probe according to the preamble part of claim 1. It includes devices for observing and illuminating a region of interest in the tip part. The NMR metering antenna is fitted to the outer periphery including the tip surface of the endoscope body and can be connected to the NMR metering apparatus.

EP patent application No. 0 385 367 discloses an insertable pickup probe which comprises an elongated shaft supporting a patient interface balloon. The interface balloon comprises an inflatable inner balloon enclosed by a flexible outer balloon and a RF receiving coil being positioned between the inner and outer balloon

and placed intimately adjacent the region of interest by inflating the inner balloon to expand outwardly against the outer balloon. The receiving coil is electrically connected to an interface network.

Summary of the Invention

It is an object of the present invention to provide an insertable, intracavity pickup probe capable of being placed in close proximity to a region of interest, particularly in the colon, to improve the quality of a magnetic resonance image or spectrum.

It is a further object of the present invention to provide an insertable MRI pickup probe capable of being manipulated by a clinician during insertion of the probe in a manner accommodating shape variations, curves, bends and the like in a body passage through which the probe is inserted.

Another object of the invention is to provide an insertable MRI pickup probe which when inserted at a site of interest in a body cavity can be manipulated so as to optimize the positioning of the pickup coil in relation to the particular area of interest.

The invention in a specific embodiment relates to an insertable, intracavity pickup probe, and more specifically an intrarectal pickup probe for high sensitivity and high resolution imaging of the colon and associated area. Although the pickup probe is described hereinafter as principally to image or obtain spectra from the area of the colon, it should be understood that the concepts outlined herein are equally appropriate for other regions of interest such as the rectum, vagina, stomach, and mouth. Additionally, the principles described herein may be applied to MRI or NMR application involving the arteries, veins, and other similar regions of the body reachable by an insertable or implantable pickup probe.

The insertable pickup probe of the present invention greatly improves the signal-to-noise ratio of an image or spectrum acquisition over signal pickup devices commonly used with MRI and NMR scanner systems. In addition, the restricted field of view of the probe reduces or eliminates image distortion caused by motion, blood flow, patient breathing, and signal aliasing when conducting an image acquisition using multidimensional fast Fourier transform techniques.

The insertable pickup probe of the present invention comprises an elongate shaft having a proximal end and a distal end, which supports an outer patient interface balloon structure at its distal end and a handle at its proximal end. The interface balloon structure contains a pickup coil having a lead extending through the shaft for connection to an interface network to receive signals from the coil. Guidance of the balloon structure during insertion into the cavity is performed by means of a rod-like mandrel which is included in the intracavity probe and which is insertable through the shaft into the balloon structure from a proximal end of the handle. The lead of the pickup coil may exit at the proximal handle end and

may be provided with a connector for attaching the coil to the interface network.

In accordance with another aspect of the present invention the balloon structure includes an outer balloon and first and second inflatable inner balloons within the outer balloon, whereby the inner balloons are located on a first and a second side of the coil, respectively, sandwiching the coil therebetween. The coil is provided in form of a closed substantially planar loop. The two internal balloons are inflatable independently by means of separate inflation tubes which extend through the shaft exiting at the proximal handle end thereof. Each tube has a stopcock or like inflation controller, and each tube is separately connectable to an inflation cuff or the like. When the probe is inserted in a body cavity with the balloon structure positioned adjacent an area of interest to be investigated by NMR or MRI imaging, the provision of the separately inflatable internal balloons allows the coil to be more effectively positioned relative to the area of interest by selective and differential inflation. For example, if the area of interest is located on the anterior side of the coil, the posterior-side internal balloon may be inflated to a higher inflation volume than the anterior-side balloon to move the coil toward the anterior.

The rod-like mandrel may have a length to extend, when inserted substantially from a distal end of the balloon structure out of the proximal end of the handle. The mandrel, which may be in the form of a stiff plastic or like rod may have a curved distal end. The effects of the curved end of the mandrel is to provide a type of orbital movement of the balloon structure and coil when the proximal end of the mandrel is axially rotated relative to the shaft during insertion of the probe, useful to provide steering of the probe through curves and the like in a body cavity. The rod-like mandrel may comprise a proximal end with a mark in order to indicate alignment of the curved distal end portion thereof. The mark may be a knob with an arrow or other mark.

According to a further feature of the present invention the shaft of the insertable intracavity probe comprises identifying means for indicating alignment of the coil. To provide an indication of the orientation of the coil, the shaft may include a longitudinal sight line or stripe aligned with the coil. In accordance with another embodiment of the invention, the probe may include steering and locator means to assist a clinician when inserting a probe in a body cavity to accommodate bends or curves in the cavity and to provide a visual indication as to the orientation of the coil. To this end, the probe may include a stiffener tube extending axially through the outer balloon from the proximal end of the shaft, and a removable steering mandrel which can be inserted into the shaft and stiffener tube substantially up to the distal end of the balloon structure.

In accordance with another aspect of the present invention the stiffener tube is rotatably mounted in distal and proximal bearings in said balloon structure whereby

rotation of the mandrel effects rotation of the stiffener tube and coil. The mandrel may be used to rotate the coil along with the anterior and posterior balloons within the outer balloon structure. To this end, proximal and distal end rotary bearings are provided within the outer balloon to receive the mandrel. The coil along with the anterior and posterior balloons may be taped together to form, with the mandrel, a rotary unit which can be rotated within the outer balloon by rotation of a knob or the like at the proximal end of the mandrel. Thus, a clinician can angularly position the coil in situ within a patient without rotation of the probe as a whole. The mandrel can be formed with indicator means to display the angular position of the coil. For indication of the angular rotation the mandrel may have a cross-sectional shape, e.g. a cruciform cross-sectional shape.

The present invention further relates to a method of magnetic resonance imaging of a region of interest within a cavity of a patient using an inserted pickup probe having an elongate shaft with a balloon structure at a distal end thereof including a pickup coil therein, whereby the elongate mandrel is inserted into the shaft and balloon structure and is used to assist in manipulation of the balloon structure during insertion of the probe by rotation of the mandrel about an axis of the shaft. The mandrel may comprise a bowed distal end and the method further comprises providing orbital movement of the balloon structure about the shaft by rotation of the mandrel. The method according to the present invention may further include the steps of inserting the pickup probe into the cavity, positioning the balloon structure proximate the area of interest, selectively rotating the coil within the balloon structure to optimally position the coil with respect to the area of interest and using the coil for imaging. The step of influencing the coil laterally within the balloon structure to obtain optimum positioning of the coil in relation to the area of interest may be included.

According to a further feature of the present invention the method further comprises insertion of the balloon structure, which includes a pickup coil and a first and a second internal inflatable balloons within the structure embracing the coil on opposite sides of the coil, respectively, into said cavity of a patient, positioning the balloon structure proximate the area of interest, providing selective and independent inflation of the internal balloons to influence positioning of the coil within the balloon structure so as to optimally position the coil in relation to the area of interest, and using the coil for imaging.

The above and other objects and advantages of the present invention will become more readily apparent when reference is made to the following description, taken in conjunction with the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a perspective view of an insertable pick-

up probe in accordance with the present invention and an associated interface network.

Figure 2 is a cross-sectional plan view of the distal balloon portion of the insertable pickup probe illustrated in Figure 1.

Figure 3 is a cross-sectional elevational view of the distal end balloon portion of the probe.

Figure 4 is a sectional view taken on line 4-4 of Figure 3.

Figure 5 is an elevational view of a steering mandrel for the probe.

Figure 6 is a plan view of the steering mandrel.

Figure 7 is a view similar to Figure 2 showing the distal balloon portion of a modified pickup probe according to the invention.

Figure 8 is an elevational view of a mandrel used in the probe shown in Figure 7.

Figures 9 and 10 are views showing alternative cross-sectional shapes for the mandrel.

Figure 11 is a cross-section view on line XI-XI of Figure 7.

Description of Preferred Embodiment

Referring first to Figure 1, an insertable colon pickup probe is shown in an assembled form at 10, and an interface network to which the probe connects is shown at 12. The pickup probe 10 is an MRI or NMR receiving device capable of imaging or gathering spectra from the human colon and surrounding tissue, but may also be used as the transmit coil for RF excitation. The probe 10 is used with the interface network 12 which provides the tuning, impedance matching, and decoupling functions.

The probe 10 includes a shaft 14 which supports a patient interface balloon structure 16 at its distal end and a handle 18 located at the proximal end of the shaft 14. As will be described in more detail later, assembly 16 includes an internal pickup coil 20 and internal anterior and posterior inflation balloons 22 and 24, none of which are shown in Figure 1. The coil and internal balloons are accommodated, as will be described, in an outer balloon 26. Tubes 28, 30 for inflating the internal balloons extend from the respective balloons through shaft 14 and exit at the proximal end of handle 18. The tubes have respective inflation control stopcocks 32, 34 and connections 36, 38 for attaching same to an inflator device 40 such as a syringe or cuff.

The receiving coil contained within the patient interface balloon structure 16 can be electrically connected to the interface 12 by an insulated interconnecting cable 42 which has a plug 44 at its proximal end for connection to terminal 46 located on the front of the interface network 12.

The interface network 12 also includes a terminal 48 for providing a connection to a MRI scanner. Furthermore, the interface network 12 may include a switch 50 capable of being moved between an operating position

and a tuning position or be designed such that it functions fully automatically. To display to the operator the mode of operation, indicator lights 52 or an LED readout are provided on the front of the interface network 12. In addition, a light 54 or an LED readout for indicating the occurrence of a probe failure is provided on the front of the interface network 12.

A removable elongate rod-like steering mandrel 56 extends through the balloon structure 16 and shaft 14. The mandrel has an operating knob 58 at its proximal end.

Referring now to Figures 2 to 4, the patient interface balloon structure 16 of the insertable pickup probe 10 is illustrated in more detail. Extending through the shaft 14 and axially through balloon structure 16 is a stiffener tube 60 which is a permanent part of the structure and which may, for example, be supported in shaft 14 by an end plate 62 and a like end plate (not shown) at the proximal end of the shaft. The lead 42 for the pickup coil 20 extends through a lumen of the tube 60 and exits the tube through an aperture 64 adjacent the distal end of shaft 14. Outside of the aperture, lead 42 connects to coil 20 which is in the form of a loop occupying a substantial cross-sectional area of the outer balloon 26.

The internal inflation balloons 22 and 24 embrace the coil 20 on its anterior and posterior sides and also occupy substantial areas of the outer balloon as shown in Figure 3. The inner balloons are connected at their distal inlet ends to the inflation tubes 28 and 30 which are shown diagrammatically only in Figure 2. The inflation tubes pass through apertures in end plate 62 and thence through the shaft 14. The inner balloons and coil 20 may be loosely held together as a sandwich-type package by an encircling cuff 66 shown dotted in Figures 2 and 3.

The mandrel 56, which is of a stiff plastic or other material, also fits through the lumen of the stiffening tube 60. As shown in Figures 5 and 6, the mandrel is linear in plan view but has a J-like bend 68 at its distal end in elevational view. Also, the mandrel operating knob 58 has an indicator mark 70 to show a clinician inserting the probe the alignment of the mandrel. Further, as shown in Figure 1, the shaft has a lengthwise indicator stripe 72 (shown dotted for convenience only) substantially aligned with the plane of coil 20.

Other constructional details and materials of the various components of the probe are generally known per se and for such details, reference may be made to copending U.S. Patent Application Serial No. 07/315,875 filed January 27, 1989. Details of the interface network are also shown and described in the copending patent application.

For insertion of the probe by way of a patient's rectum, the internal balloons 22 and 24 would be deflated to minimize the size of the structure 16, it being noted that outer balloon 26 is not inflated. During insertion of the probe, the balloon structure may be given an orbital type twisting movement by rotation of the mandrel,

should it be necessary to "steer" the probe along curves or bends in the anal tract or other intercavity passage-way.

When the balloon structure is situated at a site to be investigated by MRI or NMR imaging, the probe is manipulated in order to orientate the coil substantially face on to an area of interest. Then, for optimal positioning of the coil relative to said area, the internal balloons may be differentially inflated with the balloon on that side of the coil which is further from the area of interest being inflated to a higher volume than the balloon which is on the side of the coil facing the area of interest. Differential inflation of the balloons is effected, for example, by opening and closing the respective stopcocks 32 and 34 to allow controlled quantities of air to be delivered to the respective balloons from the inflator device 40. Differential inflation of the balloons as described has the effect of locating the coil in closer proximity to the area of interest than is possible with known forms of inflatable probe devices. Typical inflation volume for the balloons may, for example, be 40cc in each balloon for a center lumen position of the coil and 10cc in the anterior balloon and 50cc in the posterior balloon for an anterior position of the coil.

Figures 7-11 show a modified probe structure in which the coil along with the internal balloons may be rotated within the outer balloon so as to allow in situ angular positioning of the coil when in position in a body cavity without having to rotate the probe as a whole when positioned within a patient. Equivalent reference numerals are used to denote parts which are equivalent to those in the previous embodiment.

Thus, in the modified arrangement, a proximal rotary bearing 80 is provided at the distal end of shaft 14 and a similar distal rotary bearing 82 is provided in a bearing support 83 within the outer balloon 16 at its distal end. Stiffener tube 60' is supported for rotation within the bearings 80 and 82, and a relatively stiff mandrel 56' with a proximal end operating knob 58' extends through shaft 14 and tube 60'. The pickup coil 20 and the internal anterior and posterior balloons 22 and 24 are constructed in like manner to the previous embodiment, but in this case they are taped together and also taped to the mandrel by tapes 66' so as to rotate together with the mandrel and stiffener tube as a unit within the outer balloon. The mandrel may have alternative cruciform cross-sectional shapes as shown in Figures 9 and 10 received in a correspondingly shaped lumen in the stiffener tube so that rotation of the mandrel by knob 58' when the probe is *in situ* in a body cavity is effective to rotate the internal balloon assembly within the outer balloon 16. The cruciform shape of the mandrel is also useful for indicating the angular position of the coil relative to the outer balloon along with indicator 70'.

The remainder of the structure of the probe including the handle is similar to that described in connection with Figures 1-6.

In all embodiments of the invention the outer bal-

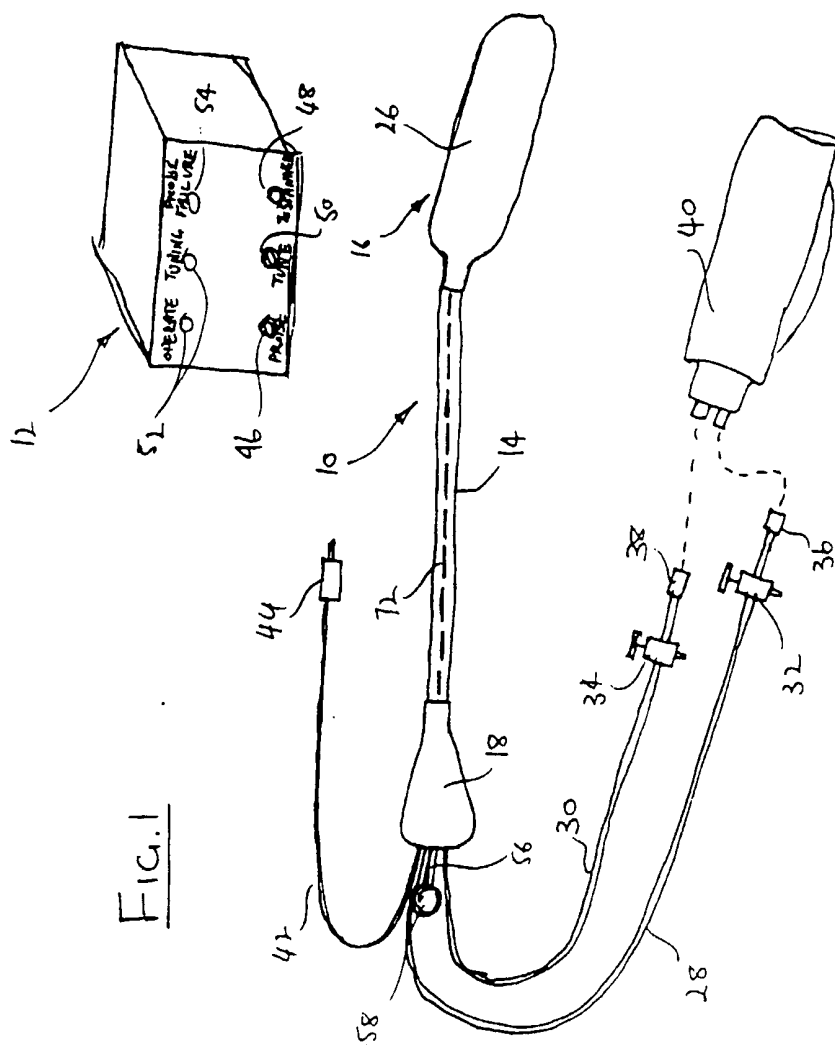
loon 16 may be disposable or covered by a disposable sheath or the like to allow for repeated use of the probe.

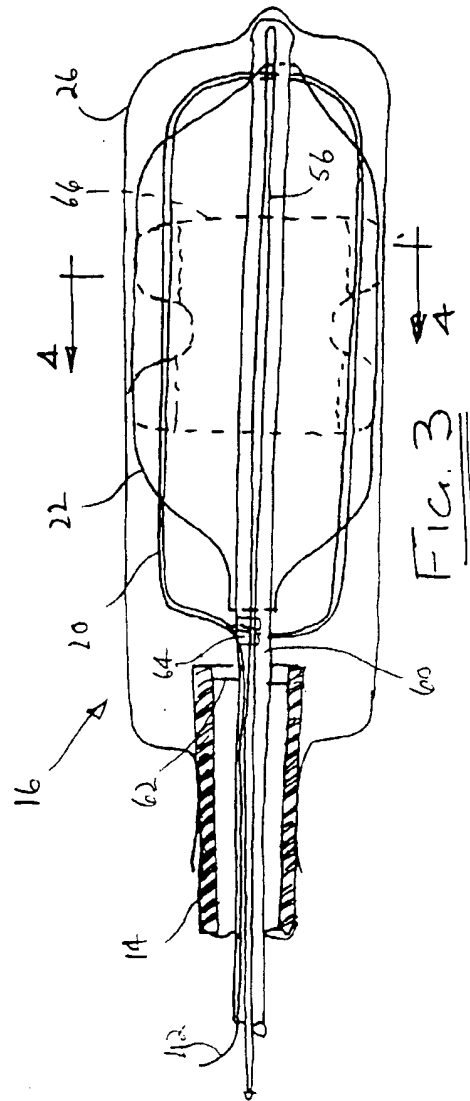
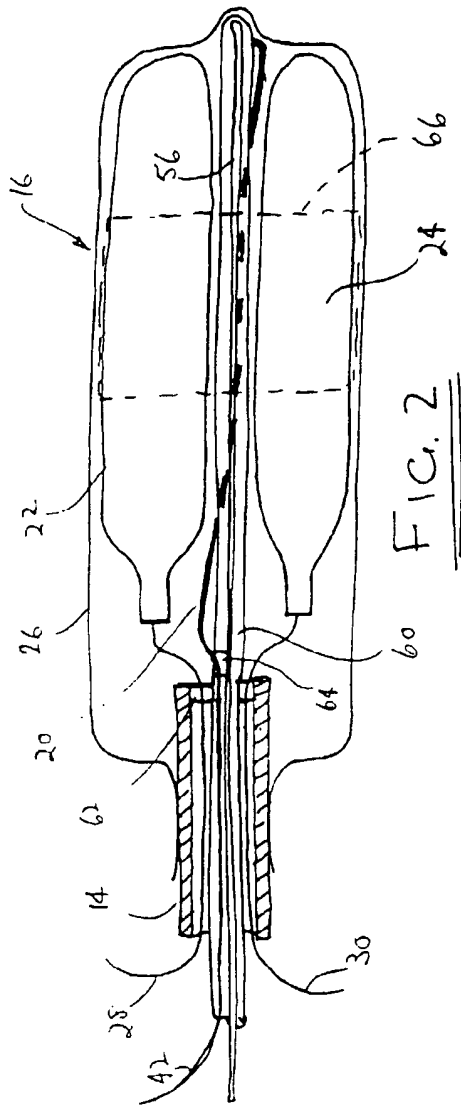
While only a preferred embodiment of the invention has been described herein in detail, the invention is not limited thereby and modifications can be made within the scope of the attached claims. Just as a few examples, the mandrel need not be curved, and with an alternate mechanism for aligning the coil, the stiffening tube need not be provided.

Claims

1. An insertable intracavity probe (10) for use in magnetic resonance imaging of a region of interest within a cavity of a patient comprising an elongate shaft (14) having a proximal end and a distal end, a handle (18) on the proximal end of the shaft (14), a balloon structure (16) on the distal end of the shaft (14) including therein a pickup coil (20) having a lead (42) extending through the shaft (14) for connection to an interface network (12) characterized in that said intracavity probe (10) includes an elongate rod-like mandrel (56) insertable through the shaft (14) into the balloon structure (16) from a proximal end of said handle (18), and being arranged to provide guidance of the balloon structure (16) during insertion into the cavity.
2. The invention as defined in claim 1 characterized in that said balloon structure (16) includes an outer balloon (26) and first and second inflatable inner balloons (22, 24) within the outer balloon (26), said inner balloons (22, 24) being located on first and second side of said coil (20), respectively, sandwiching said coil (20) there between, and respective inflation tubes (28, 30) for inflating said inner balloons (22, 24) extending through said shaft (14).
3. The invention as defined in claim 2 including control means for selectively and individually controlling inflation pressure for said respective inner balloons (22, 24).
4. The invention as defined in claim 3 characterized in that said control means includes a stopcock (32, 34) on each inflation tube (28, 30) and connector means (36, 38) for attaching said tube (28, 30) to an inflation source (40).
5. The invention as defined in any one of claims 1 - 4 characterized in that said rod-like mandrel (56) having a length to extend, when inserted substantially from a distal end of the balloon structure (16) out of the proximal end of the handle (18).
6. The invention as defined in any one of claims 1 - 5

- wherein said rod-like mandrel (56) has a curved distal end portion (68) for providing orbital twisting movement of said balloon structure (16) on said shaft (14) when said mandrel (56) is rotated in said shaft (14).
7. The invention as defined in any one of claims 1 - 6 characterized in that said rod-like mandrel (56) has a proximal end with a mark (70) for indicating alignment of said curved distal end portion (68) of said mandrel (56).
 8. The invention as defined in any one of claims 1 - 7 characterized in that said rod-like mandrel (56) has a knob (58) at the proximal end and said mark (70) is on said knob (58).
 9. The invention as defined in any one of claims 1 - 8 characterized in that said shaft (14) includes identifying means for indicating alignment of said coil (20).
 10. The invention as defined in claim 9 characterized in that said identifying means is a longitudinal stripe (72) or like mark on said shaft (14).
 11. The invention as defined in any one of claims 1 - 10 characterized in that said balloon structure (16) includes a stiffener tube (60) extending from the shaft (14) through the balloon structure (16) and wherein the mandrel (56) fits in a lumen in the stiffener tube (60).
 12. The invention as defined in claim 11 characterized in that said stiffener tube (60) is rotatably mounted in distal and proximal bearings (80, 82) in said balloon structure (16) whereby rotation of said mandrel (56) effects rotation of said stiffener tube (60) and coil (20).
 13. The invention as defined in any one of claims 1 - 12 characterized in that said balloon structure (16) includes attachment means (66') within the outer balloon (26) securing said coil (20) to said stiffener tube (60) and mandrel (56) for rotation therewith whereby said coil (20) can be angularly rotated and positioned within said balloon structure (16) by rotation of said proximal end portion of the mandrel (56').
 14. The invention as defined in claim 13 characterized in that said attachment means (66') also secures said inner balloons (22, 24) to said stiffener tube (60) and mandrel (56) for rotation therewith.
 15. The invention as defined in any one of claim 1 - 14 characterized in that said mandrel (56') has a cross-sectional shape for indication the angular orientation within said balloon (16).
 16. The invention as defined in claim 15 characterized in that said mandrel (56') has a cruciform cross-sectional shape.
 17. Method of magnetic resonance imaging of a region of interest within a cavity of a patient using an inserted pickup probe (10) having an elongate shaft (14) with a balloon structure (16) at a distal end thereof including a pickup coil (20) therein, characterized in that an elongate mandrel (56) inserted into said shaft (14) and balloon structure (16) is used to assist in manipulation of said balloon structure (16) during insertion of said probe (10) by rotation of said mandrel (56) about an axis of said shaft (14).
 18. Method as defined in claim 17 characterized in that said mandrel (56) has a bowed distal end (68) and the method further comprises providing orbital movement of said balloon structure (16) about said shaft (14) by rotation of said mandrel (56).
 19. Method as defined in any one of claims 17 - 18 characterized in that the steps of inserting said pickup probe (10) into said cavity, positioning said balloon structure (16) proximate said area of interest, selectively rotating said coil (20) within said balloon structure (16) to optimally position said coil (20) with respect to said area of interest and using said coil (20) for said imaging are included.
 20. Method as defined in any one of claims 17 - 19 characterized in that the step of influencing said coil (20) laterally within said balloon structure (16) to obtain optimum positioning of said coil (20) in relation to said area of interest is included.
 21. Method as defined in claim 17 characterized in that the steps of inserting said balloon structure (16), including a pickup coil (20) and first and second internal inflatable balloons (22, 24) within said structure (16) embracing said coil (20) on opposite sides of said coil (20), respectively, into said cavity of a patient, positioning said balloon structure (16) proximate said area of interest, providing selective and independent inflation of said internal balloons (22, 24) to influence positioning of said coil (20) with said balloon structure (16) so as to optimally position said coil (20) in relation to said area of interest, and using said coil (20) for said imaging are included.
 22. Method as defined in claim 21 which further includes rotating said coil (20) and inner balloons (22, 24) with said balloon structure (16) to obtain optimal positioning of said coil (20).





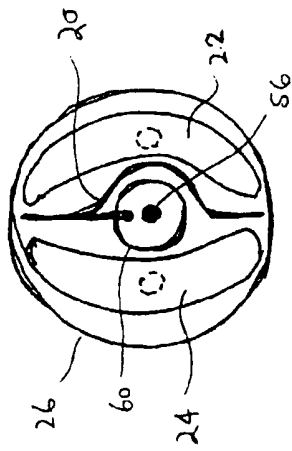


FIG. 4

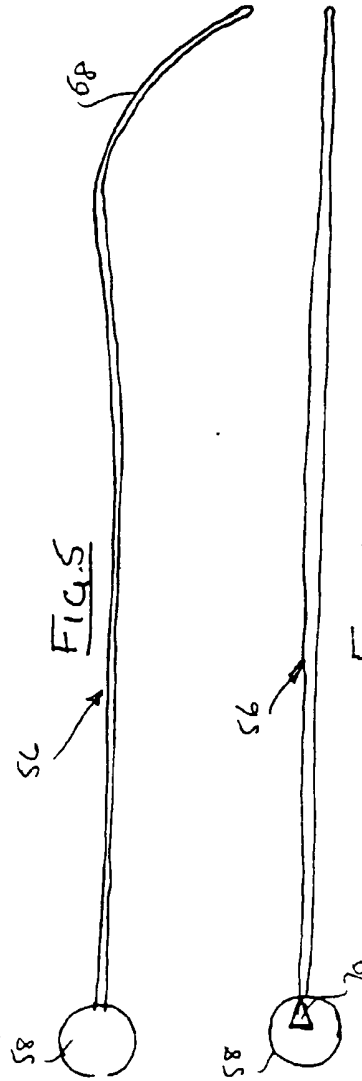


FIG. 5

FIG. 6

